Freeway Management Systems for Transportation Efficiency and Energy Conservation

Overview

Transport Canada
Transports Canada

Canada

Published by:
Transportation Development Centre
Transport Canada

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Produced by:
Synergistics Consulting Limited

September 1985

Published by Authority of the Minister of Transport, Government of Canada;

Nº de Catalogue No. T48-23/1985E
ISBN 0-662-14138-5

TP6343E

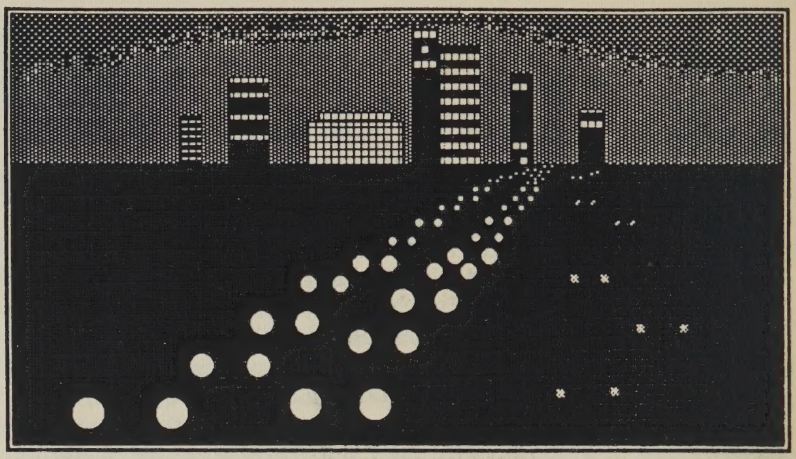
Preface

The 1973 oil embargo and subsequent price increases have ensured that fuel supplies will never again be taken for granted in Canada. Indeed, energy has emerged as an important factor in public policy-making at every level. The need for this is most evident in the transportation sector where fully half of all our petroleum is consumed. Much of this consumption occurs within urban areas, in major travel corridors and in downtown street networks. It is here that significant opportunities still exist to conserve fuel and other valuable resources by implementing traffic management measures designed to alleviate congestion and reduce peak travel demands. These measures not only reduce fuel consumption; they also make the flow of traffic smoother and safer, and travel times more predictable, reduce air pollution levels, and help defer large investments otherwise required for new roadway capacity.

The United States has adopted national legislation to realize these benefits through transportation system management (TSM) measures. Canada, on the other hand, has taken a voluntary approach. Many provinces and municipalities have included requirements for the conservation of energy and monetary resources in their evaluation processes and subsidy criteria for the provision of transportation infrastructure and service. Similarly, the Federal Government has recognized the need for energy conservation through traffic management in urban areas.

The purpose of this booklet is to introduce senior officials concerned with urban freeway systems to traffic management techniques that can help maximize the operating efficiency of existing freeways. A companion "Planning Guide" (see inside back cover) provides more detailed information on these measures for planners and engineers. It is hoped that these publications will encourage implementation of freeway management systems in Canada.

New Solutions To An Old Problem



Freeway traffic jams are frustrating, dangerous and costly — but they are also controllable.

The obvious costs of lost time, unnecessary fuel consumption and increased air pollution are all significant. But the cost of building more freeway capacity to accommodate peak travel demands can be prohibitive.

In the past, many urban transportation agencies tried to alleviate traffic problems solely by constructing new road facilities. Yet the problems have remained. Given today's financial constraints and the mounting evidence that simply adding more freeway capacity does not solve the problems, traffic engineers are increasingly turning to transportation system management (TSM) techniques for the solution.

These proven, low-cost techniques, when properly applied, optimize key aspects of the operation of existing freeway facilities, thereby increasing capacity without major new construction. In addition to being cost-effective, freeway management techniques do not encourage additional travel, which traditionally occurs when new freeway facilities are built.

Freeway Management Systems

Proven transportation system management (TSM) techniques, systematically applied to a freeway facility or corridor, constitute a freeway management system. A successful freeway management system will:

- improve traffic flow and safety
- reduce energy consumption
- improve air quality
- save money & raw materials

Such a system can begin with a single measure applied at a single location, or it can involve a set of complementary measures applied to an entire transportation corridor. The measures can be as simple and time-tested as increasing the frequency of police and tow-truck patrols. Or, they can involve the installation of sophisticated electronic sensors connected to a central computer facility.

Generally, the most successful freeway management systems involve a number of mutually reinforcing techniques along with a high level of communications and control applied to transportation corridors that include, in addition to the freeway and its interchanges, all freeway service roads and parallel arterial roads.

Goals

Successful freeway management systems are more than simply collections of individually promising techniques. System components are carefully chosen, planned and orchestrated to meet the following goals:

1. To maintain the maximum operational capacity and level of safety of the existing facilities and to reduce delays caused by congestion.

2. To increase the quality and quantity of current information available to both system managers and system users (motorists, truckers), to enable them to make informed decisions.
3. To enable system managers to exercise some measure of control over the volume and routing of traffic, when necessary to optimize system efficiency and capacity — e.g. for daily commuting and special events.
4. To maximize the person throughput rather than simply the vehicle throughput capacity of the facility by encouraging a shift to higher occupancy vehicles.
5. To conserve resources — especially energy and money — and to improve air quality.

Types of Freeway Management Systems

Spot Location	System is implemented at a specific location on a freeway
Linear Facility	System is implemented on a single freeway (usually limited to mainline and major ramps)
Mini-Corridor	System includes the freeway mainline, its ramps, and service and frontage roads
Corridor	System includes the freeway mainline, its ramps, service and frontage roads; parallel freeway or other limited access facility; and the network of transverse roadways
Area-Wide	System encompasses all freeways within a metropolitan area — often linked to the control system of the arterial street network.

System Components

The four major components of a freeway management system that are required to successfully meet these goals are:

A Incident Management. Continually monitoring freeways and related facilities to detect and define traffic flow problems; and quickly responding to remove impediments and minimize delays to drivers.

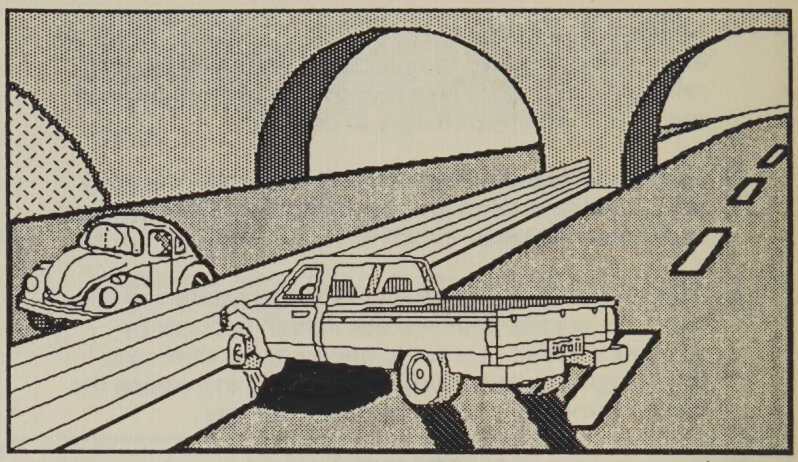
B Driver Information. Providing information on freeway conditions to drivers; and enabling the drivers to divert to alternative routes.

C HOV Preferential Treatment. Offering preferential or exclusive access and facilities to high occupancy vehicles (HOVs), in order to encourage a shift away from single occupant vehicles, thereby increasing the person throughput capacity of the freeway.

D Communications and Control. Establishing a two-way flow of up-to-the-minute information between the central control facility and the field equipment to enable freeway managers to exercise the necessary control of traffic flow.

Freeway management techniques that have proven effective in achieving these objectives are outlined in the following sections of this booklet. For a summary of these techniques, see page 16.

Incident Management



To keep a freeway facility operating up to its potential, it is vital that the location and nature of any problems on the roadway be quickly identified. The objective is to return the roadway to its full carrying capacity as quickly as possible, thereby minimizing delays to motorists.

Delays, of course, can be caused by many different situations — accidents, vehicle breakdowns, lane closures due to maintenance or construction activity, or "rubbernecking" by motorists driving by the scene of the incident. The proven three step approach for dealing with these incidents consists of:

- **Incident detection**
  — electronic surveillance
- **Incident verification**
  — remote citizens band (C.B.) monitoring
  — closed circuit television
- **Incident response**
  — tow truck or heavy equipment

Detection

Fast detection and verification of incidents are important elements of effective traffic management. One of the primary techniques used in incident detection systems for major freeway management projects is electronic surveillance. In most systems, loop detectors are embedded in each lane of the roadway at intervals of approximately 800 metres. These provide a picture of traffic congestion by determining 'occupancy'. In other words, they measure the time that a vehicle occupies the space directly over a loop detector. By comparing readings between stations, incidents such as a major accident blocking an entire roadway can be quickly detected. In this situation, 'upstream' detector stations would have high occupancy readings because of traffic build-up and 'downstream' stations would indicate no readings since vehicles would be trapped behind the offending accident.

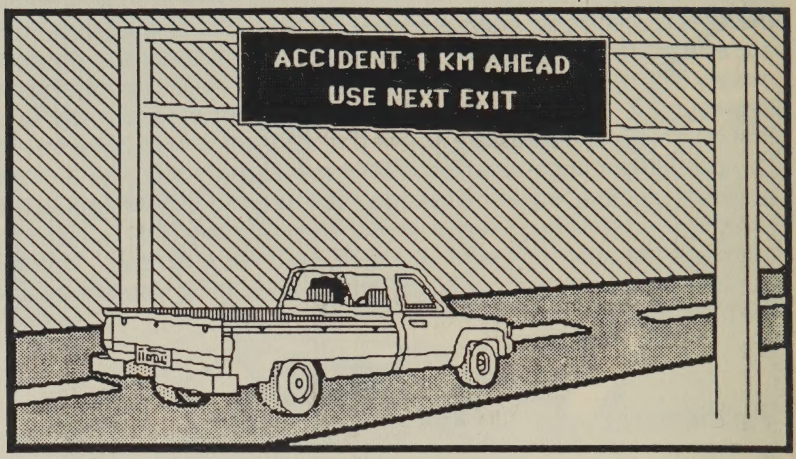
Verification

If a patrol vehicle is used to spot incidents, the appropriate response can be immediately dispatched to the scene. With electronic surveillance, on the other hand, the specific nature of the problem will need to be verified. This can be accomplished by television cameras, by police patrols or citizens band radio remote monitoring. At many locations, the last method — i.e. communicating with C.B. radio users in the vicinity of an incident location — has proven particularly cost-effective.

Response

Rapid response to freeway problems means the quick return of a roadway to normal flow conditions. Once a problem has been detected and its type and severity determined, the appropriate vehicles must be dispatched to provide emergency service and to clear the problem site. To expedite response, courtesy vehicles, police cars and tow trucks can be directed to patrol the roadway during the morning and afternoon peak traffic periods or to station themselves close to habitual trouble spots, such as bridges, tunnels and interchanges.

Driver Information Systems



Effective two-way communication between freeway managers and motorists reduces motorist frustration and improves traffic flow by enabling freeway managers to offer guidance and exercise control in the following areas:

- traffic management and diversion (incident management, special event advisory and speed control)
- warning of adverse conditions (weather and road conditions)
- control during construction and maintenance
- control of special lanes (reversible, exclusive and restricted lanes)

In their most advanced form, driver information systems can operate as traffic diversion and alternative routing systems. These aim to improve traffic flow by redistributing peak travel demands to better match the available capacities of all parallel facilities in a commuter corridor. They can also minimize overall delays caused by construction or maintenance activity by advising motorists of the best routes to reach particular destinations.

Information Channels

Information can be provided to motorists in a variety of ways. The major methods are: variable message signs, highway advisory radio, in-vehicle guidance systems, and trip planning services.

Variable Message Signs

Variable message signs can be either small single-message signs or larger signs displaying a number of messages, much like score-boards at sports stadiums. A certain number of predetermined messages can be included in the software program of the system. In addition, an unlimited number of site- or incident-specific messages can be displayed by entering each message directly through a keyboard in the control centre.

While a variety of variable message signs are available, magnetic disk signs are increasing in use since they provide low power consumption, low maintenance costs, and high reliability. The disks have the sign background colour on one side and a contrasting colour on the other. The disks are pivoted and flipped from one side to the other electro-magnetically.

Highway Advisory Radio

Highway Advisory Radio (HAR) Systems or "audio signing" may be used in addition to or as an alternative to variable message signs, to provide motorists with real-time traffic information. Signs posted along the highway advise motorists to tune car radios to a particular AM station to receive traffic information on roadway conditions in the immediate area. Where HAR can be used in place of variable message signs, substantial cost savings can be realized.

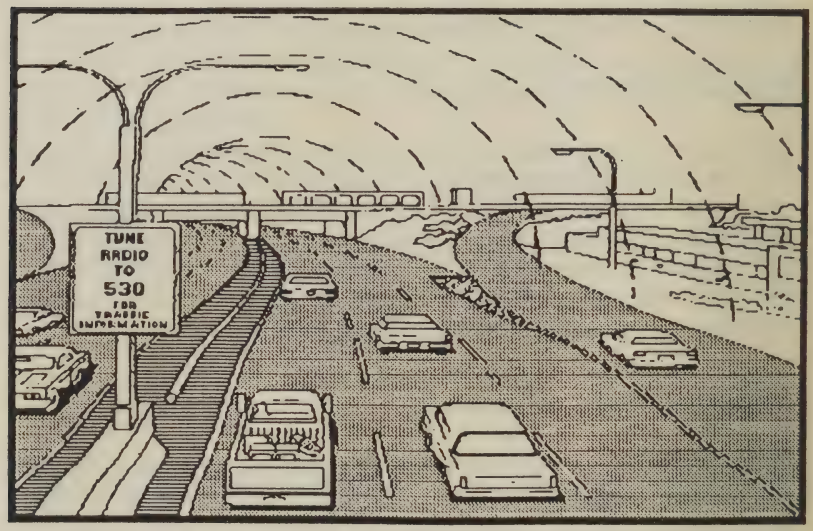
In-Vehicle Guidance Systems

While not yet commercially available, in-vehicle guidance systems will provide drivers with specific routing instructions automatically. Each driver enters his location and intended destination into an electronic device in the vehicle. This information is picked up by a roadside receiver and communicated to a central computer control facility. Suggestions are then transmitted back to the driver via an in-vehicle visual display.

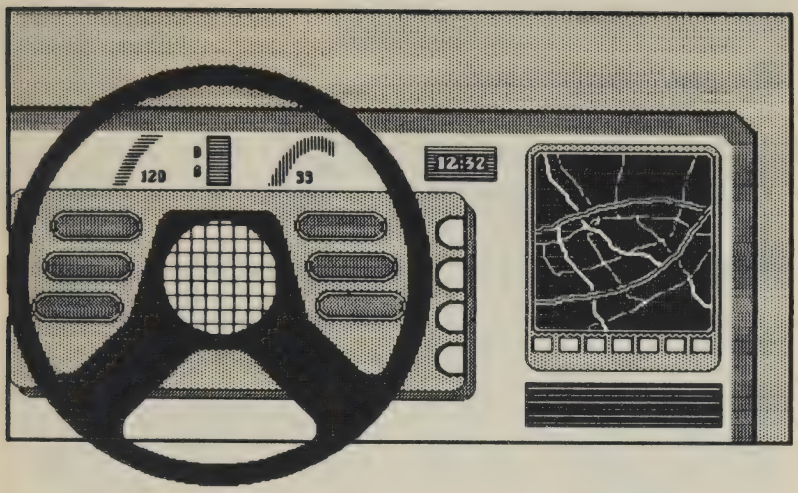
Trip Planning Services

Trip planning services provide information on actual traffic conditions so that drivers may select the best route, before commencing a trip. During unusual conditions, such as severe snow storms , highway agencies can also advise surrounding businesses of the best time to release employees so that heavy traffic will not interfere with snow-clearing operations. It is most important that the information provided by trip planning systems be updated constantly. If users find traffic conditions different from those described, they will quickly start ignoring the system.

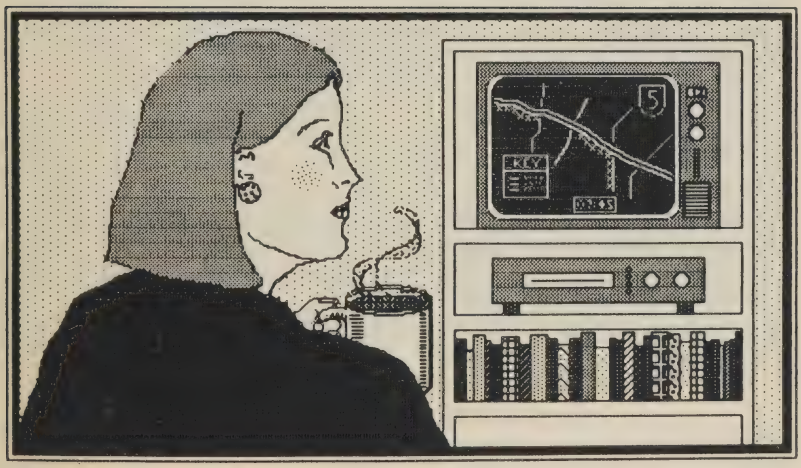
The various techniques used in trip planning systems include: telephone call-in service, teletype communication systems, cable TV traffic channels (for transmitting information directly to homes), and giant display screens in sports and entertainment centres, lobbies of major employment complexes and at exits of parking garages.



HAR Coverage — Cable Radiator Antenna

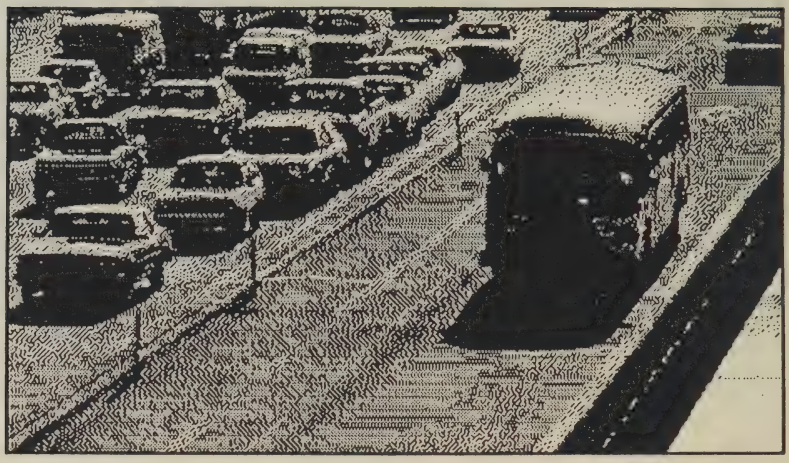


In-Vehicle CRT Display



Trip Planning via Cable TV

HOV Preferential Treatments



High Occupancy Vehicle (HOV) systems represent a fundamental but logical change in freeway management philosophy. They provide preferential treatment to vehicles containing several occupants, optimizing the person throughput capability (rather than simply vehicle throughput) of road facilities.

High occupancy vehicles are considered to deserve better access to and from cities during peak periods because each HOV takes up only one "slot" in the traffic stream to transport several people — compared to single occupant vehicles (SOVs) which require a full slot for only one person. Because of this superior efficiency, traffic engineers implementing HOV preferential treatments also feel that a higher speed is justified for HOVs, which serves to encourage the formation of additional car, van and bus pools and greater use of public transit.

Approaches

Preferential treatment for High Occupancy Vehicles (HOVs) can take different forms.

1. **Construction of Exclusive HOV Road Facilities.** This can include the construction of freeways exclusively designated for use by HOVs during the peak periods; the construction of a "bus way", or lane exclusively reserved for buses and perhaps other HOVs; and the construction of reversible exclusive lanes in the median of an existing freeway.

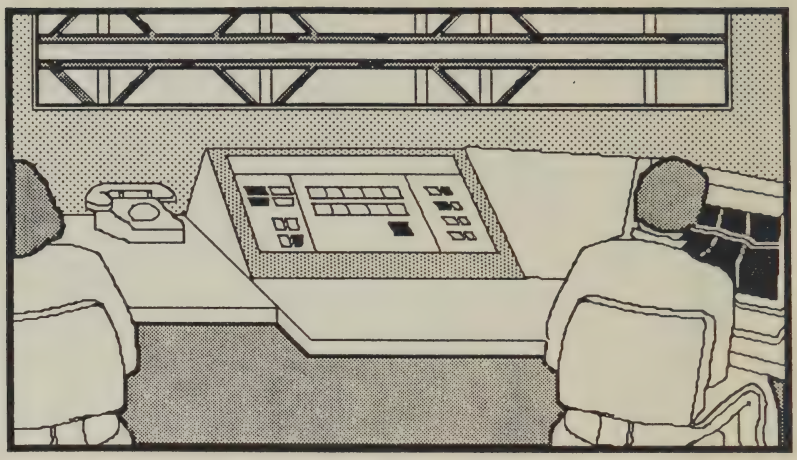
2. **Designation of Existing Freeway Lanes as Exclusive HOV Lanes.** These can be concurrent flow lanes (with traffic flow), pre-empting usually one travel lane from peak direction lanes; or contra-flow lanes, pre-empting the centremost lane from the off-peak direction.

3. **Designation or Construction of HOV Preferential Ramps.** These give car, van, and bus pools priority or even exclusive entry to and from the freeway at specific locations during morning and evening peak periods.

4. **Designation or Construction of HOV Preferential Parking.** This can involve the construction of parking lots close to major freeway interchanges and/or the designation of parking facilities nearest to downtown employment concentrations as exclusive HOV facilities.

5. **Establishment of Traffic Signal Pre-emption System for Transit Vehicles.** These allow transit drivers to change traffic signals to green, or extend the green time, minimizing their stopped time at these signals. This is done by installing special transmitters in buses and streetcars, and corresponding receivers in selected signal control cabinets.

Communications and Control Facilities



An efficient communications system and a computer control facility constitute the central nervous system and the brain of a freeway management system. The two-way communications system transfers information from the various field components to the central computer control room and transmits responses and commands back to the field. A good system is one of the most important (and costly) elements in freeway management.

Communications Systems

The type of communications system chosen depends on the size and complexity of the freeway management system. Ultimately, the selection depends upon the specific conditions of the site and the various control elements in the system.

The primary communications media used in freeway management systems are twisted wire pairs, coaxial cable, fibre optics cable and radio transmission.

Selection criteria include reliability, ease of maintenance, and flexibility for change or expansion. Another major consideration is whether to utilize a system leased from the telephone or cable TV utility company or to install an agency-owned system. Implementation, cost and time factors are also prime concerns. All these considerations must be fully weighed to select a communications system that will best meet the needs of a particular location.

Centralized Computer Control Facility

Centralized computer control facilities perform the functions of receiving and analysing all data obtained from the various field components, determining appropriate control strategies and measures, then transmitting directions and commands back to specific field equipment.

The selection of a computer for central control centre must be based on the size of the system to be controlled and the means by which field data is collected. These factors will influence the required memory capacity and operating speed of the computer. In some systems, two or three small computers are coupled and the tasks of managing the system are divided among them. This method provides backup if one of the computers fails and may prove more effective than utilizing one large computer.

In addition to computer equipment, centralized control facilities usually contain peripherals such as: CRT video displays, display maps, radio monitors, cassette tape equipment (with pre-recorded messages), and control consoles for variable message signs, and other field equipment.

Summary of Freeway Management Techniques

Incident Management

Detection
- electronic surveillance
- patrol vehicle
- aerial surveillance
- CB radio
- emergency phone
- call box

Verification
- closed circuit TV
- remote CB monitor
- police patrol

Response
- courtesy patrol
- police patrol
- tow trucks
- heavy duty equipment

Communications and Control

Field Control
- ramp meters
- overhead lane signs

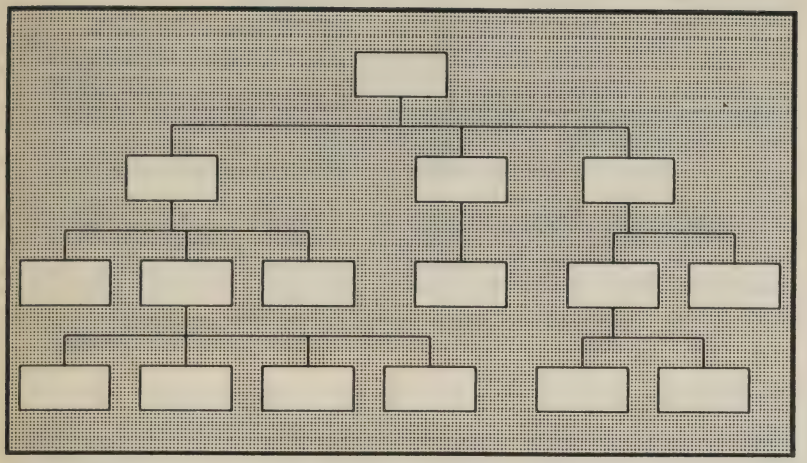
Communications
- twisted wire pairs
- coaxial cable
- fibre optics cable
- radio transmission

Central Control Facility
- computer equipment
- map & video displays
- radio monitors
- cassette tape equipment

Driver Information
- variable message signs
- highway advisory radio
- in-vehicle guidance
- trip planning

HOV Treatments
- exclusive facility
- designation of existing lane
- preferential ramp entry
- preferential parking
- signal pre-emption

Implementation



Making a freeway management system fully operational is a challenging managerial assignment. The design and implementation of an appropriate system starts with careful setting of project goals and objectives. These are used to design management approaches and to select system components. An implementation plan can then be developed to guide all stages of putting the system into place.

Key Design Parameters

Recent experience with freeway management systems has shown the following to be important considerations in designing successful operating systems.

Scale of Application

Corridor or area-wide management systems offer significant advantages over systems covering a single location or freeway because they allow for the application of route diversion techniques. These enable the freeway management team — upon detecting a capacity

restriction on one of the corridor roadways — to reroute traffic to less-congested alternative roadways, by transmitting information to the drivers using variable message signs or highway advisory radio.

Integration of Complementary Components

A major focus in the design of freeway management systems is packaging a number of mutually-reinforcing techniques together to attain maximum overall effectiveness. This is particularly important when implementing preferential treatments for high occupancy vehicles (HOVs). By concurrently providing incentives for HOVs and disincentives for single occupancy vehicles (SOVs) through the entire length of a corridor, individual measures can be less penalizing to SOVs while the HOVs will still gain a significant door-to-door travel advantage, by accumulating savings at each location (eg. entry ramp, exclusive lane, exit ramp, downtown parking).

Phasing

While it is important to design a long-term freeway management strategy for a metropolitan area, it is also important to be able to offer immediate benefits to motorists. Phasing the design and implementation of the freeway management system provides both short and long term benefits, and it allows a manager to work within jurisdictional and funding constraints.

The Implementation Process

Once the goals and objectives of a freeway management strategy have been established and the system has been designed, an implementation process can be set in motion.

Planning

Developing detailed implementation plans for the main components of the freeway management system is required to secure system funding and to ensure cost-effective implementation. These include:

- an internal marketing plan — to enlist the support of management personnel

- a public relations plan — to communicate with news media, freeway users and public-at-large
- a funding plan — to budget and obtain sufficient funds
- an educational plan — to increase the knowledge and expertise of those involved in the project
- an operating and maintenance plan — to provide staff with a step-by-step approach for the operation and maintenance of the system
- an evaluation plan — to measure cost-effectiveness and efficiency of the system

Involvement

It is particularly important to gain the participation and cooperation of all the agencies and groups that will be affected by or involved in the freeway management system. Their involvement should begin at the problem identification stage and continue throughout the design, implementation, operation, evaluation and enhancement stages of the project.

The number and diversity of affected agencies and groups can be surprisingly large, encompassing provincial, municipal and federal government agencies, transit operators and parking authorities, car/van pool and taxi associations, automobile clubs, trucking associations, chambers of commerce, tow truck operators, contractors and transportation consultants, among others.

Evaluation

A rigorous evaluation process is required to select techniques for the freeway management system, to determine the degree of improvement provided by the system, and to identify required modifications and additions. As in any evaluation, measures of effectiveness need to be established, before and after studies conducted, and cost/benefit analyses performed.

Many freeway management operations evaluate the performance of the individual techniques and the overall system on a daily basis.

Information collected for this purpose is used periodically to document the substantial benefits of low-cost freeway management techniques, as compared to those achieved by constructing expensive new roadway or transit facilities.

Existing projects in Canada and the United States prove that freeway management systems can be successfully implemented to achieve the ultimate goal of increasing the efficiency of passenger and freight transportation in major urban corridors, while conserving valuable resources — money, energy and environment.

Freeway Management Systems Development & Implementation Phases

1 Problem Identification
2 Goal-Setting
3 Feasibility Study
4 System Design & Approval
5 Equipment & Contractor Selection
6 Consultation & Coordination
7 Phased Implementation
8 System Integration & Acceptance Testing
9 Operation & Maintenance
10 Monitoring & Evaluation
11 System Refinement

Freeway Management Systems for Transportation Efficiency and Energy Conservation — series includes the following reports:

- Summary of North American and European Projects TP6640E
- Bibliography of Key References TP6639E
- Practical Planning Guide for Traffic Engineers TP6220E
- Overview TP6343E

Systèmes de gestion d'autoroutes visant à maximiser les économies d'énergie et l'efficacité des transports routiers — Aperçu général

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- Guide de planification pour ingénieurs en circulation TP6220F
- Aperçu général TP6343F

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